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A SNACK-BASED RATION CONTAINING CAFFEINE INCREASES CALORIC INTAKE AND IMPROVES COGNITIVE PERFORMANCE

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14. ABSTRACT

Warfighter cognitive performance degrades during sustained operations in part due to difficulty consuming adequate calories and limited access to stimulants such as caffeine. This investigation tested the effectiveness of a snack-based ration, containing caffeinated components, to increase energy and preserve cognitive performance during sustained operations. Eighty-nine Marines consumed either an entree-based (MRE) or a snack-based (FSR) ration during a four-day field exercise with limited sleep. Outcome measures included visual reaction time, logical reasoning, mood state (POMS), and energy intake. Total calories, CHO and caffeine intake was greater ($P<0.05$) for FSR compared to MRE in part due to a significant increase in the number of daily eating episodes in those consuming the FSR ($P<0.05$). Reaction time was faster and fewer lapses in attention occurred in Marines consuming the FSR compared to MRE ($P<0.05$). There was no difference in logical reasoning between groups. Overall mood deteriorated over the course of the exercise with no difference between ration groups.

15. SUBJECT TERMS

Caffeine, meal frequency, reaction time, First Strike Ration (FSR)

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A SNACK-BASED RATION CONTAINING CAFFEINE INCREASES CALORIC INTAKE AND IMPROVES COGNITIVE PERFORMANCE

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BACKGROUND

The First Strike Ration (FSR) is a compact, eat-on-the-move individual ration designed to be consumed during short-term, high-intensity missions of approximately 3-7 days. It substantially reduces the size and weight burden relative to current individual, general-purpose field ration (MRE), and its eat-on-the-move capabilities are expected to enhance consumption, nutritional intake, and mobility. Prototype versions of the FSR have received high acceptability and desirability scores (Montain et al. 2006a).

USARIEM has conducted three field studies that compared the FSR (w/caffeine supplement) to MRE. Initially, the acceptability of the FSR was tested with 124 Warfighters performing patrol missions in eastern Afghanistan (Montain et al. 2006a). Of those consuming the FSR over a 3 day mission, 68% reported that they liked the FSR "moderately" or "extremely" (8 & 9 on 9 point scale), and 63% reported that they would prefer the FSR over the MRE for their next mission. Only 20% preferred the MRE over the FSR. A collaborative effort with the USDA Forest Service and the University of Montana (Montain et al. 2006b) followed to investigate the performance association of the FSR. In this study, the efficacy of FSR for sustaining self-paced work productivity and cognitive performance capability of wildland firefighters was assessed during 2 days of fire suppression work. It was found that volunteers consuming the FSR (with supplemental carbohydrate and caffeine) performed 30 min of more moderate intensity work per day ($p<0.05$) and rest 30 min/day less ($p<0.05$) than when they were provided 2 MRE per day (Montain et al. 2006b). Total two day energy intake (5250±580 vs. 4396±599 kcal/ 2 day), carbohydrate intake (698±76 vs 545±82 g/2 day) and caffeine intake (347±262 vs. 55±65 mg/2 day) were greater ($p<0.05$) when eating FSR than MRE, respectively. No differences in cognitive performance were observed, but the firefighters all had a full nights (~8-9 h) sleep between shifts minimizing the likelihood of cognitive deficits due to work stress. A follow on study collected blood samples and measured activity profiles of firefighters consuming either FSR (w/caffeine) or 2 MREs per day (Ely et al. 2008). The FSR was shown to sustain blood markers of fuel availability and nutrition status as effectively as the MRE, and workers consuming the FSR tended to perform more self-paced work each work shift.

Based on recommendations from the Institute of Medicine's Food and Nutrition Board, and USARIEM experiments, the FSR has been modified to contain additional carbohydrate and protein while keeping the size and weight less than 0.12 cu feet and 2.8 lb, respectively. Insertion of new food components and improved ergonomics of existing products are expected to improve eat-on-the-move capabilities. Our previous work (Montain et al. 1997, 2006b; Lieberman et al. 2002a) and those of others (Cuddy et al. 2007; Cerra et al. 2003; Maffucci and McMurray 2000), suggest that regular intake of carbohydrate will lead to improved physical performance. Specifically, we observed that Soldiers performing long-hours of strenuous activity were less capable of performing a series of military-relevant tasks if they refrained from eating carbohydrate during the hours of labor preceding the performance tasks (Montain et al. 1997). Moreover, our lab (Lieberman et al., 2002a) has demonstrated the benefit of frequent carbohydrate intakes, during about 10 hours of physically demanding activity when regular meal provision did not meet energy requirements. In that study, carbohydrate supplementation, in the form of six administrations of a carbohydrate beverage enhanced physical performance, mood, and vigilance of Army Rangers during a scenario that simulated the timing and intensity of the physical demands of a combat mission. Two different concentrations of beverage were tested, 6% and 12%, which provided carbohydrate at ~15 g/hr and 30 g/hr, respectively. The results revealed a significant dose-related response.

The FSR was approved for accelerated fielding and became available for purchase in the fall 2008. The Nutritionally Optimized FSR (NOFSR) ATO is a product improvement effort to improve the performance capabilities of the original FSR. The final milestone of the NOFSR ATO is demonstration of the NOFSR operational capabilities. This study is designed to demonstrate the efficacy of the NOFSR for improving cognitive performance when the NOFSR is consumed as experimentally designed (i.e., periodic snacking) compared to consuming field rations in the traditional meal platform pattern. Sub experiments are included to further our understanding of how stress alters/modifies nutritional markers and stress-response proteins and possible attenuation with diet. This research supports USARIEM ATO D.OS.2005.02 (Nutritionally Optimized First Strike Ration).

ACKNOWLEDGMENTS

The authors would like to thank the men and women of Marine Officer Training Course at Quantico, VA who made this study possible, Paul Maguire for his assistance with ration development and data collection, and Dr. Jennifer Rood for her assistance with the caffeine and cortisol analysis.

EXECUTIVE SUMMARY

Warfighter cognitive performance degrades during sustained operations in part due to difficulty consuming adequate calories and limited access to stimulants such as caffeine. This investigation tested effectiveness of a snack-based ration which contained several components designed to increase energy and caffeine intake and thereby preserve cognitive performance during sustained operations. Eighty-nine Marines (n=80 men; n=9 women) consumed either an entrée-based ration (two MRE™: 2700 kcal, 364 g carbohydrates (CHO), 15 mg caffeine) or a snack-based ration (FSR®: 3200 kcal, 513 g CHO, 623 mg caffeine) during a four-day field exercise with limited sleep. Outcome measures included visual reaction time, logical reasoning, mood state (POMS), and energy intake (calculated from food records and collected wrappers). Total calories (2048[66] kcal vs. 1800[69] kcal), CHO (319[10] g vs. 229[10] g), and caffeine (319[13] mg vs. 10[17] mg) intake was greater for FSR® compared to MRE™ in part due to a significant increase in the number of daily eating episodes in those consuming the FSR® (5[1] vs. 4[1]). Reaction time was faster and fewer lapses in attention occurred in Marines consuming FSR® compared to MRE™. There was no difference in logical reasoning between ration groups. Overall mood state deteriorated over the course of the exercise with no difference between ration groups. A snack-based ration increased total energy, CHO and caffeine intake, improved reaction time and decreased lapses in vigilance during four days of military training.

INTRODUCTION

During military operations Warfighters can be undernourished due to very high levels of energy expenditure, disrupted sleep and limited opportunity to eat (Baker-Fulco 1995; Lieberman et al. 2002b; Tharion et al. 2004). In the civilian sector, wildland firefighters, disaster victims, and relief workers can experience similar situations. Long hours of physical labor and repeated mental challenges without restorative sleep and adequate nutrition can produce profound effects on physical work capacity, vigilance and simple reaction time (Lieberman et al. 2002b;Lieberman et al.2006, Opstad et al. 1978) which have been documented both in the field and laboratory simulations (Dinges and Kribbs 1991; Kreuger 1989; McLellan et al.2005b).

It is well documented that carbohydrate (CHO) (Coyle 2004; Horswill et al. 1990; Lieberman et al. 2002a; Montain et al. 2008) or caffeine (McLellan et al. 2005a, 2005b, 2007) intake improves vigilance, mood and physical performance during prolonged sleep deprivation (Lieberman et al. 2002a; McLellan et al. 2007). Regular consumption of a CHO beverage during moderate physical activity has been shown to enhance auditory vigilance and mood (Lieberman et al. 2002a). Caffeine, an adenosine receptor agonist, modifies CNS neural activity and increases wakefulness (Goldstein et al. 1969), enhances vigilance (Rosenthal et al. 1991; Zwyghuizen et al. 1990), and improves work shift performance (Walsh et al. 1990). Many studies (Lieberman et al. 2002b;, McLellan et al. 2005a, 2005b, 2007) have shown that repeated caffeine doses maintain cognitive function during prolonged sleep deprivation. Recurrent CHO intake improves physical performance at moderate- to high-intensity levels (Cuddy et al. 2007; Lieberman et al. 2002a; Maffucci and McMurray 2000; Montain et al. 1997; Montain et al. 2008) and increases self-paced activity during occupational labor (Cuddy et al. 2007). Consistent findings have led to the general recommendation that athletes consume 30-60 g CHO/hr during activity to improve endurance performance (Coggan and Coyle 1991; Currell and Jeukendrup 2008; McConell et al. 1996; Rodriguez et al. 2009).

Military ration developers have formulated an *eat-on-the-move* snack-based ration (First Strike Ration®, FSR®) which requires no preparation (from wrapper to mouth with no heating required) with the objective to increase overall caloric consumption by encouraging repeated eating episodes. In addition, caffeine is included in some food items to sustain mental and physical performance. In an initial test of the efficacy of the FSR®, users had increased voluntary eating episodes and therefore increased caloric, CHO and caffeine intake in addition to increased self-paced activity compared to an entrée-based ration (Montain et al. 2008). The effectiveness of FSR® consumption for sustaining cognitive performance during military scenarios with marked sleep loss has not been examined.

This study evaluated the impact of ration composition on the cognitive performance of individuals participating in multiple days of arduous work with limited sleep. It was hypothesized that increased intake of calories, CHO and caffeine would reduce cognitive performance and mood decrements typically observed during multiple days of sustained operations.

METHODS

Eighty-nine United States Marine Corps personnel (n=80 men; n=9 women) were recruited from a Marine Officer Training Course at Quantico, VA from two separate course iterations. The study was approved by the Human Use Review Committee at the United States Army Research Institute of Environmental Medicine, Natick, MA. Volunteers who indicated that they were vegetarian, pregnant, or older than 55 yrs were excluded from participating. All volunteers gave written informed consent following an explanation of study procedures in a formal brief.

RESEARCH DESIGN

Marine Officer Training was an ideal study population as this training environment includes simulated combat-like scenarios performed as near-continuous activity over a four-day period. Volunteers were stratified by body weight and then randomly assigned to either an entrée-based ration group or a FSR® group. The entrée-based ration contained components of two Meals, Ready-to-Eat™ (MRE™) and a supplemental placebo snack pack (non-caloric drink, non-caloric gel, and non-caffeinated gum). The FSR® group received a sandwich-based ration containing components of FSR® distributed as a ration plus a snack pack (caloric drink, caloric gel, and caffeinated gum) daily during the four-day study (Table 1). For presentation purposes, data are grouped by day 1 (<24-hrs); day 2 (25-48-hrs); day 3 (49-72-hrs); day 4 (73-96 hrs). A four-menu MRE™ cycle was selected for each volunteer to match the repetitive cycling of the two FSR® experimental menus. Volunteers were required to consume only the ration they were administered and had unrestricted access to potable water. All ration components met standard food safety and microbiological regulatory requirements.

DATA COLLECTION

Ration intake was *ad libitum* with two exceptions. First, volunteers were strongly encouraged to consume snack pack items at periodic intervals throughout the day. Second, volunteers were directed to consume two pieces of caffeinated gum (~200 mg) ~ 60 min prior to cognitive testing. Energy intake was calculated on study days 1-4 from a combination of volunteer completed food records and verification from collected food wrappers (Figure 1). Final intake data was calculated from chemical analysis when available as well as computer generated ration nutrient profiles (Genesis R&D® SQL, ESHA Research, Salem, OR). Ration opinion questionnaires were completed following the study to assess ration acceptability (portion sizes, variety, food combinations, and overall food quality), as well as human factor issues related to usage and satisfaction with the ration packs.

Salivary measures of caffeine and cortisol were obtained daily in conjunction with the cognitive tests using unstimulated saliva on an untreated cotton collector (Salivette®, SARSTEDT, Germany). Samples were frozen at -20°C until analysis. Analysis was conducted by Pennington Biomedical Research Center (Baton Rouge, LA) using Beckman Coulter DXC 600 Pro (Brea, CA).

Energy expenditure was quantified by Actimetry (Actical®, MiniMittter Respironics, Inc., South Bend, OR). Volunteers were fitted with an actigraph on their wrist throughout the study period. Activity was differentiated into the categories: sedentary (0-149 counts/min^{-1}), light (150-849 counts/min^{-1}), moderate (849-4999 counts/min^{-1}), and vigorous (4900+ counts/min^{-1}) using the manufacturer supplied software algorithms. Sleep was quantified by the sum of minutes of activity that was less than 25 counts min-[1], as measured by actigraphy between the hours of 2300 and 0600.

Cognitive function and mood were assessed daily with three tests administered using hand-held personal digital assistant (Palm III; Palm, Inc, Sunnyvale, CA). The three tests were: Psychomotor Vigilance Test (PVT), a test of simple visual reaction time; Grammatical Reasoning, a test of logical reasoning capability; and the Profile of Mood States (POMS), a measure of mood state. Volunteers were familiarized with the cognitive tests and POMS on two separate occasions three days prior to the four days of arduous work. All three cognitive tests took approximately 15 minutes to complete.

Cognitive Testing

Psychomotor Vigilance Test (PVT). This is a test of simple visual reaction time (Dinges and Powell 1985). A series of stimuli are presented at random intervals on a screen and the volunteer must respond as rapidly as possible when a stimulus appears. Parameters recorded include reaction time, false alarms and number of performance lapses (responses ≥3 seconds were defined as major lapses and minor lapses if responses between 0.5 -3 seconds). The test requires volunteers to sustain attention and respond as rapidly as possible to a randomly appearing stimulus on a computer screen by pressing a button.

Grammatical Reasoning. This test assesses language-based logical reasoning and has been used to assess the effects of various treatments on cognitive function (Braddeley 1968). It has been adapted from the Baddeley Grammatical Reasoning Test. On each trial, the letters AB or BA follows a statement. The volunteer must decide whether or not each statement correctly describes the order of the two letters. Statements can be positive/negative or active/passive, and a given letter may precede/follow the other letter.

Profile of Mood States (POMS) Questionnaire. The POMS is a widely used, standardized, computer or paper-and-pencil administered inventory of subjective mood states (McNair et al. 1971). It is sensitive to a wide variety of nutritional manipulations, environmental factors, sleep loss and sub-clinical doses of various drugs (Banderet and Lieberman 1989; Lieberman et al. 2002a, 2002b, 2005; Shukitt-Hale et al. 1997). It has been used extensively in the laboratory and field in combination with cognitive tests. The volunteers rate a series a 65 mood-related adjectives on a five-point scale, in response to the question, "How are you feeling right now?" When analyzed, the adjectives yield six mood sub-scales (tension, depression, anger, vigor, fatigue, and confusion).

STATISTICAL ANALYSIS

Baseline ration group characteristics (e.g. height, weight) were compared using non-paired t-tests. The effect of ration and field training on activity, cognitive performance and dietary intake were assessed using mixed model ANOVA with ration as an independent factor and time as the dependent factor. Bonferroni procedure was used to identify differences among means following detection of significant main or interaction effects. The practical importance of diet effects on performance were also examined by comparing the mean and 95% confidence intervals (CI) for group differences (diet – baseline) against an evidentiary standard other than zero, similar to equivalence testing. This procedure is a corollary for significance testing and provides insight into the importance of the effect magnitude. The threshold of importance was established as the typical within-subject variability (noise) in the performance measurement. Data were analyzed using Statistica (version 7.1) and SPSS (version 17) statistical software. Data are presented as mean [sd]. A *P* value ≤ 0.05 was considered significant.

RESULTS

By design there were no differences in weight between the two ration groups, body weight averages were 79[10] kg for MRE™ and 78[11] kg for FSR®. The FSR® group consumed more calories ($P<0.05$) and CHO ($P<0.05$) than the MRE™ group (Figure 2) over the four days of testing. Protein intake did not differ between ration groups (FSR® 55[22] g, MRE™ 57[19] g) throughout the study. However, fat intake was elevated in the MRE™ group as compared to the FSR® (74[27] g vs. 60[21] g, respectively; $P<0.05$). Caffeine intake was higher for FSR® group compared to MRE™ ($P<0.05$) (Figure 2). The total FSR® caffeine intake was greatest in the first 24 hr (day 1) and was stable throughout day 2 and 3 (Figure 2). Additionally, individuals consuming the FSR® had a modest but significantly greater number of daily eating episodes than those consuming the MRE™ (5 [1] vs. 4 [1], respectively; $P<0.05$). Both groups reported they ate throughout the day as time permitted with lack of time described as the primary reason for a decrease in total caloric intake. Overall, FSR® had a greater acceptability compared to MRE™ in terms of component variety and tolerability (as gathered from post-study questionnaires; data not shown).

Salivary cortisol levels were similar between ration groups (baseline, 0.47[0.19] µg mL^{-1}) with no change over the four study days (-12% change; $P>0.05$). The median salivary caffeine levels were higher in the FSR® group compared to the MRE™ group; on day 1 (0.3 µg mL^{-1} vs. 0.2 µg mL^{-1}), day 3 (9.3 µg mL^{-1} vs. 0.8 µg mL^{-1}) and day 4 (4.4 µg mL^{-1} vs. 0.3 µg mL^{-1}). Median values are presented due to sample bias, samples were collected within a short period of time (<60 minutes) after consumption of caffeine containing products.

Individuals who consumed the FSR® spent less time sedentary compared to those who consumed the MRE™ (30[0.81] % vs. 33[0.84] % daily activity, respectively; $P<0.05$) and a similar amount of time performing light (50[0.74] %, 48[0.77] %) and moderate activity (19[0.66] %, 18[0.69] %) over the four-day study. Although there appeared to be a trend towards greater daily activity counts in the FSR® group as compared to MRE™ (636,425[16,392] vs. 597,688[17,172] , respectively) differences were not significant ($P=0.62$). Average estimated sleep time was initially 225[36] minutes but declined over the four-day period to 182[41] minutes (day 4) for both ration groups.

The demands of the training course produced a slowing of the PVT reaction time. The magnitude proved diet dependent, as reaction time was faster for Marines consuming the FSR® compared to those consuming the MRE™ ($P<0.05$) (Figure 3A). The impaired reaction time of the MRE™ group was well outside the expected day-to-day variation (4%; shaded area) whereas with FSR® the confidence interval overlapped with the expected day-to-day noise. Minor lapses in vigilance (responses between 0.5 - 3 seconds) increased in both diet groups over time, however the MRE™ group had a significant increase in the number of minor lapses ($P<0.05$) compared to FSR® (Figure 3B). The ability of volunteers to correctly answer logical reasoning test questions improved over time ($P<0.05$) with no differences between ration groups.

The four-day training course produced a deterioration of mood as reflected by an increase in total POMS score ($P>0.05$), but no difference between rations (Figure 4A). The increase in total POMS score was primarily the result of increased subjective fatigue (6.1[5.6]) and reduced vigor (-4.0[6.4]), and modest increases in subjective confusion (1.5[3.1]), anger (2.0[6.5]), depression (1.6[3.6]) and tension (1.0[4.5]) (Figure 4B).

DISCUSSION

This study demonstrated that the cognitive decrements resulting from several days of arduous work and sleep deprivation are attenuated by the combination of regular snacking and increased caffeine consumption. Consistent with our hypothesis, there was less deterioration of vigilance and fewer attention lapses in the group consuming the FSR® compared to the MRE™. These results combined with previous findings (Montain et al. 2008) suggest that a snack-based ration (FSR®) containing caffeine is better than a traditional ration for sustaining cognitive and physical performance in a healthy population exposed to multiple stressors.

Sustained cognitive performance in the FSR® group could be attributed to increased caloric intake, especially of CHO, the acute effects of caffeine, or both. Consistent with earlier findings (Montain et al. 2008) the FSR® group had greater energy intake, consumed a greater quantity of CHO, and ate more frequently than those consuming an entrée-based ration (MRE™). Not only did volunteers consume the

FSR® more often, they reported liking the ration components more than the MRE™ thereby encouraging an increase in food consumption when time permitted. These outcomes are also consistent with previous studies reporting that caffeine administration can attenuate the degradation of vigilance accompanying sleep disruption/deprivation during military field exercise (McLellan 2005a, 2005b, 2007). By design, no effort was made to separate the effects of additional energy, CHO or caffeine. The FSR® was formulated based on research findings indicating that CHO (Coyle 2004; Horswill et al. 1990; Lieberman et al. 2002a; Montain et al. 2008) and caffeine (Lieberman 2002b; McLellan et al. 2005a, 2005b, 2007) are each effective in sustaining vigilance and mood during multiple days of heavy work. The objective of this effort was to test whether a ration that incorporated these strategies would produce the anticipated benefits when consumed in an operational environment.

Previous research has shown frequent CHO intake improves physical performance (Cuddy et al. 2007; Lieberman et al. 2002a; Maffucci and McMurray 2000; Montain 1997, 2003). The current work is consistent with earlier work that examined the impact of a snack-based ration on self-selected activity (Montain et al 2008), as volunteers consuming the CHO-rich FSR® spent less time performing sedentary activity as compared to the MRE™ group ($P<0.05$). However, this study was unable to detect statistical differences between diets for the amount of time spent performing light- and moderate-intensity activities. The latter discordance may be explained by the differences in populations studied, rather than the lack of a real effect. In the earlier FSR® study (Montain et al. 2008), the dietary intervention utilized wildland firefighters who function as a group to accomplish a task, but whose individual activities are unconstrained, whereas, the current study utilized military volunteers that perform activities as a group whereby individual activity is constrained by the activity of others in the group.

The positive effects associated with the FSR® occurred despite little differences between the response of the diet groups to the strain accompanying the four-days of arduous work. In contrast to our hypotheses, the CHO-rich, caffeine-containing, *eat-on-the-move* ration had relatively modest effects on subjective mood state. Mood state did deteriorate over the four-day field exercise, but the changes in total mood state were not statistically different between the FSR® and MRE™ groups. Moreover, salivary cortisol levels remained similar to baseline over the observation period. The minor changes in these markers, known to be sensitive to stressful situations, suggest that the course imposed a relatively modest stress on the volunteers or that our assessments, taken early in the day before the rigors of the course set in, failed to capture the stress imposed by the field exercise.

The present study was designed so that blood caffeine levels would be distinctly different between diet groups at the time of cognitive testing. This was done to demonstrate the potential of a caffeine-enhanced ration to boost performance, if the ration components were used as intended. The effect size reported may underestimate the true improvement experienced, as several volunteers were remiss at chewing the gum ~60 minutes prior to cognitive testing; instead chewing the gum ~15 minutes before testing initiation. Regardless, the positive effects produced might be restricted to the time periods where the blood caffeine levels are sufficiently high to produce physiological effects. Therefore, the efficacy of the FSR for sustaining performance might be less than described herein if the caffeinated components remain uneaten when provided for *ad libitum* consumption. Future studies are necessary to test if the prescribed caffeine dosing utilized in this study is as effective if caffeine intake is *ad libitum*.

CONCLUSIONS

The present study has demonstrated the effectiveness of a snack-based ration to enhance intake of total calories, CHO, and caffeine compared to an entrée-based ration. The increased consumption improved cognitive performance during four days of arduous work with little sleep compared to a traditional ration. These findings support the recommendation for a high CHO, caffeine-enhanced, *eat-on-the-move* ration to aid in the cognitive and physical effectiveness of Warfighters under multiple military stressors.

RECOMMENDATIONS

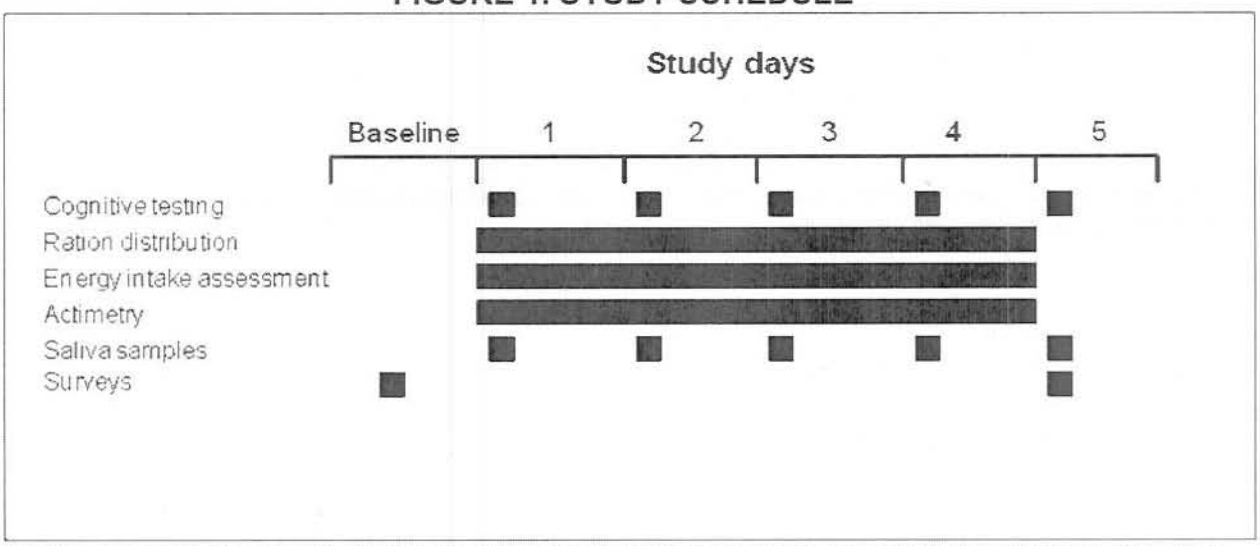
Continue development and product improvement of the FSR to include a variety of caffeine containing products to meet the demands and needs of the operational force-users.

TABLE 1. NUTRIENT COMPOSITION OF RATIONS

Nutrient	FSR		MRE	
	Mean	Range	Mean	Range
Energy (Kcal/day)	3235	3178-3291	2677	2599-2760
Protein (g/day)	86	85-87	79	74-92
Carbohydrate (g/day)	513	503-522	364	321-400
Fat (g/day)	95	88-101	103	91-116
Caffeine (mg/day)	623	620-626	14.6	9-43

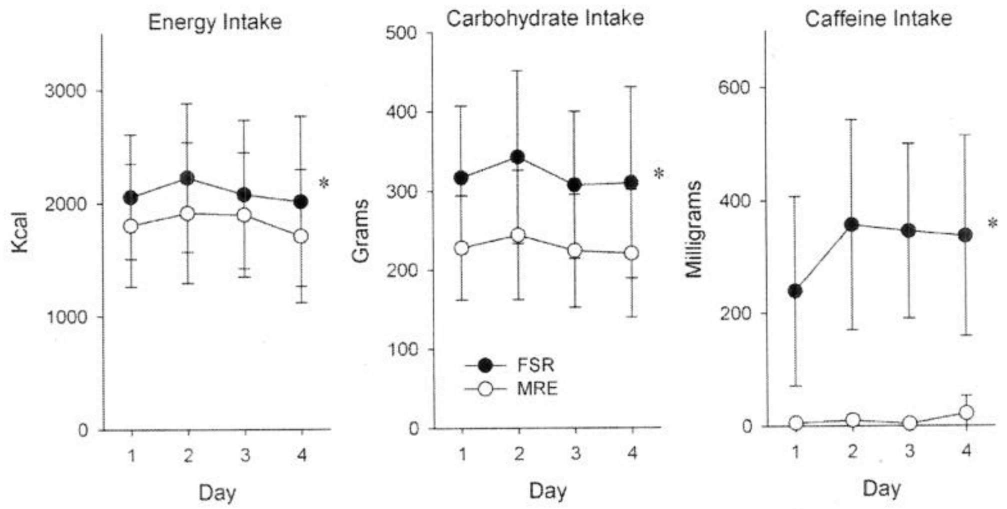
Data represents menu means for FSR (2 menus) and MRE (6 menus) assuming the entire ration was consumed.

FIGURE 1. STUDY SCHEDULE



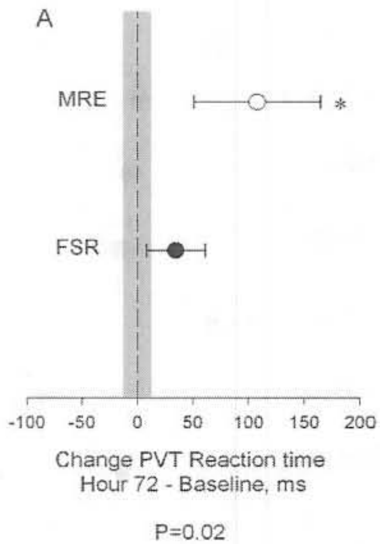
Baseline consisted of a cognitive testing practice sessions and administration of a baseline survey three days prior study day 1.

FIGURE 2. DIETARY INTAKE



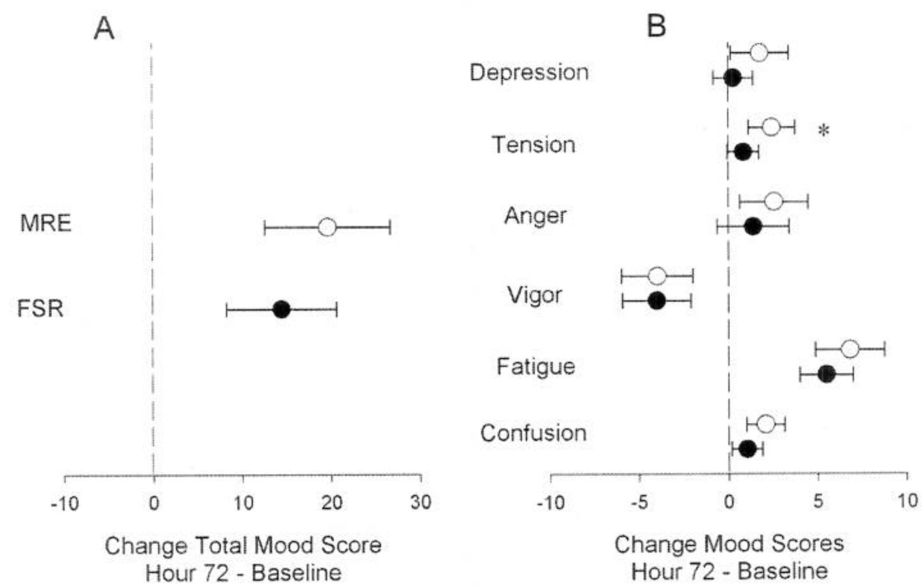
Intakes represent group averages daily estimated by a combination of self-reported food records and food wrapper verification. * (P<0.05) between diet groups.

FIGURE 3. REACTION TIME AND MINOR LAPSES MEASURED BY PVT



Simple visual reaction time and lapses were measured daily using the Psychomotor Vigilance Test (PVT). Average reaction times (A) and minor lapses (B) are presented as group averages MRE™ (○) and FSR® (●) ± 95% CI. The shaded area along the y-axis represents the zone of indifference (4% coefficient of variance). * (P<0.05) between diet groups.

FIGURE 4. DAILY MOOD ASSESSMENT



Mood state was assessed daily using the Profile of Mood States (POMS). Total (A) and sub-mood (B) scores are presented as group averages MRE™ (○) and FSR® (●) ± 95% CI. * (P<0.05) between diet groups.

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